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MILK ANALYSES.

By S. P. SHARPLES, S.B.

VII.

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Presented, Nov. 8, 1876.

In my former paper on this subject, read before the Academy last December, I gave the results of the analyses of a number of specimens of milk from the vicinity of Boston. Since that time I have had occasion to examine critically the method of analysis which I was led to adopt by my experiments, as then reported, and the results were so satisfactory that I have extended my investigations further upon the subject of pure milk as produced by cows of different breeds and by the same cow under different conditions. The pure milk for these experiments was kindly furnished me by Dr. E. L. Sturtevant, and was in each case drawn under his own supervision.

The method of analysis followed was first to determine the specific gravity, by weighing 100 cc. of the milk: this was then set for cream; 25 cc. were precipitated by acetic acid and the sugar determined. Five cubic centimetres were carefully weighed, evaporated to dryness, again weighed, the fat dissolved out by benzine, the solids not fat weighed, and then the ash determined by ignition. The caseine was determined by difference, and of course includes all the albumen and other substances of this nature that exist in the solids not fat after the abstraction of the sugar and ash.

The test analyses, with two exceptions, were made on samples of adulterated milk, which were seized during the past year by the milk inspector of the city of Lynn.

Analysis No. I. *April* 1, 1876.

Cream	5%
Sp. Gr.	1.020

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	2.86	2.86	2.860
Caseine	2.99	3.00	2.995
Ash	.42	.42	.420
Solids not Fat .	6.27	6.28	6.275
Fat	2.15	2.18	2.165
Total Solids . .	8.42	8.46	8.440
Water	91.58	91.54	91.560
	100.00	100.00	100.000

In each case, a single precipitation of the caseine and fat for the purpose of determining the sugar was made; but the solution was titrated at least twice, and the average of the results, which never varied more than a cc., taken as the amount of sugar.

This method of determining the sugar has been condemned by many chemists; but, if the precaution is taken of preparing a fresh solution every time a series of determinations are made, the results will, so far as I have experimented, be found to be comparable with each other, and those determinations made in the same sample of milk will agree very closely with each other.

Analysis No. II. *April* 8, 1876.

Cream	6%
Sp. Gr.	1.0215

	Analysis No. 1	Analysis No. 2.	Average.
Sugar	3.45	3.45	3.450
Caseine	2.78	2.79	2.785
Ash	.48	.47	.475
Solids not Fat .	6.71	6.71	6.710
Fat	2.31	2.31	2.310
Total Solids . .	9.02	9.02	9.020
Water	90.98	90.98	90.980
	100.00	100.00	100.000

Analysis No. III. *April* 14, 1876.

Cream 4%
Sp. Gr. 1.022

	Analysis No 1.	Analysis No. 2.	Average.
Sugar	3.74	3.74	3.74
Caseine	3.28	3.26	3.27
Ash	.56	.56	.56
Solids not Fat .	7.58	7.56	7.57
Fat	2.32	2.34	2.33
Total Solids . .	9.90	9.90	9.90
Water	90.10	90.10	90.10
	100.00	100.00	100.00

Analysis No. IV. *May* 2, 1876.

Cream 5%
Sp. Gr. 1.023

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.36	3.36	3.360
Caseine	3.25	3.22	3.235
Ash	.50	.50	.500
Solids not Fat .	7.11	7.08	7.095
Fat	2.25	2.25	2.250
Total Solids . .	9.36	9.33	9.345
Water	90.64	90.67	90.655
	100.00	100.00	100.000

Analysis No. V.

Cream 8%
Sp. Gr. 1.0255

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.96	3.96	3.960
Caseine	3.64	3.69	3.665
Ash	.45	.45	.450

Solids not Fat .	8.05	8.10	8.075
Fat	3.30	3.30	3.300
Total Solids . .	11.35	11.40	11.375
Water	88.65	88.60	88.625
	100.00	100.00	100.000

ANALYSIS No. VI. *August* 2, 1876.

Cream 8.5%
Sp. Gr. 1.023

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.04	3.04	3.04
Caseine	3.62	3.66	3.64
Ash	.43	.43	.43
Solids not Fat .	7.09	7.13	7.11
Fat	2.18	2.14	2.16
Total Solids . .	9.27	9.27	9.27
Water	90.73	90.73	90.73
	100.00	100.00	100.00

ANALYSIS No. VII. *August* 28, 1876.

(Sample of milk known to be pure.)

Cream 5%
Sp. Gr. 1.030

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	3.94	3.94	3.940
Caseine	4.81	4.82	4.815
Ash	.65	.65	.650
Solids not Fat .	9.40	9.41	9.405
Fat	2.47	2.49	2.480
Total Solids . .	11.87	11.90	11.885
Water	88.13	88.10	88.115
	100.00	100.00	100.000

ANALYSIS No. VIII. *August* 28, 1876.

(Sample known to be pure.)

Cream	18%
Sp. Gr.	1.033

	Analysis No. 1.	Analysis No. 2.	Average.
Sugar	4.19	4.19	4.19
Caseine	5.23	5.17	5.20
Ash	.72	.72	.72
Solids not Fat	10.14	10.08	10.11
Fat	4.35	4.35	4.35
Total Solids	14.49	14.43	14.46
Water	85.51	85.57	85.54
	100.00	100.00	100.00

These last two were samples of pure milk furnished by Dr. Sturtevant. After finishing the first analysis of each, I was led to suspect that there must be some error in No. VII., as the total solids are low for a pure milk. I therefore repeated both analyses, taking a second sample from the bottles some five or six hours after the first samples were taken, with the above results. The above eight are not selected analyses, but are all the duplicate analyses I have made up to this time.

These analyses, with the exception of the two last, having been made for legal purposes, it became necessary to compare the results with some standard taken arbitrarily to represent an average pure milk. The standard of 12.5 per cent total solids has been chosen by many chemists, following Mr. Wanklyn in this respect.

It is in all probability a little too low for this vicinity; but it has been adopted for the reason that the courts have generally ruled that, provided a milk-dealer keeps his milk above the quality of the poorest milk that has ever been analyzed, he is to be regarded as selling pure milk, and is therefore not liable to conviction for adulteration. The suit for adulteration being a criminal suit and not a civil suit for damages, the defendant is given every advantage, and the public is forced to be contented if the milk is as rich in total solids as the poorest milk that a half-starved cow was ever known to give. A much more just way to the consumer and to the producer would be to give in the law a certain

standard below which the solids in milk should not be allowed to fall. This might be even as low as 12 per cent. This low figure would be better than the present system, because, in the first place, the consumer would get a better article than he now gets, when all milk that contains over 10.75 per cent of solid matter has to be passed as pure. The producer would fare better also, since by stopping the sale of watered milk, or rather that portion of watered milk that falls below 12 per cent of total solids, the demand would be increased for pure milk. As it is now, the majority of dealers seem to prefer to buy seven-eighths or less of the milk that they need and make up the balance with water, since water costs considerably less than milk.

It seems to be pretty generally conceded that the producer very rarely waters the milk that he delivers to the middlemen or contractors. These deliver to the owners of milk routes, who sell to private families or to stores, from whence it is delivered to the consumer. The owners of the milk routes are the ones who are generally accused of adulterating the milk.

Such a law as that mentioned would, therefore, only diminish their profits, while both the producer and contractor would be better satisfied; for the market would be better and the consumer would be better served. It may be urged, on the other hand, that milk being an uncertain animal product, dependent on various circumstances for its richness and strength, — any one of which circumstances may at any time become abnormal, and so change the value of the milk, — therefore it would be unjust to establish any fixed standard below which the solids should not fall. The answer to this is that the milk of well-fed cows, in good health, rarely, if ever, falls below 11.5 per cent of total solids, and that it will average over 13 per cent of total solids, and that by establishing the standard at 12 per cent, with a margin of half a per cent for exceptional cases, no injustice is done to any one, while the public would be decidedly benefited.

The average milk containing 12.5 per cent of solids should have about the following composition: —

	Theory.	Actual Analysis.
Sp. Gr.	1.030	1.031
Cream	8%	6%
Sugar	4.40	4.32
Caseine	4.30	4.27
Ash	.60	.64

Solids not Fat	9.30	9.23
Fat	3.20	3.27
Total Solids	12.50	12.50
Water	87.50	87.50
	100.00	100.00

For comparison I have annexed the figures as given by an actual analysis of a sample of milk which contained 12.5 per cent of total solids.

In determining the amount of added water for the information of the court, we may use any one of several of the determinations given; that is, we may compare the total solids, when we have the proportion

$$12.5 : a :: 100 : x$$

a representing the amount of total solids found, and x the amount of pure milk in the sample; or we may use the proportion

$$9.3 : b :: 100 : x$$

b represents the amount of solids not fat. A third proportion is

$$4.4 : c :: 100 : x$$

c representing the percentage of sugar as found. In order to show how nearly the amount of added water as determined by these three methods agree, I will give, in addition to the six samples of adulterated milk already given, a few more samples of milk suspected of being adulterated, and then give the amount of pure milk and the amount of added water in each sample as determined by each of the above proportions. I also include in the table three other samples of milk known to be pure, but which would be condemned by one or more of the above tests.

Analysis.	Sugar.	Caseine.	Ash.	Solids not Fat.	Fat.	Total Solids.		Sp. Gr.	Cream.
No. IX.	3.52	3.37	.46	7.35	2.45	9.80	90.20	1.025	9
„ X.	3.53	3.25	.43	7.21	3.37	10.58	89.42	1.024	9
„ XI.	3.52	3.11	.52	7.15	2.10	9.25	90.75	1.024	6
„ XII.	3.53	3.59	.48	7.60	2.07	9.67	90.33	1.025	6
„ XIII.	3.73	3.40	.48	7.61	2.53	10.14	89.86	1.026	8
„ XIV.	4.88	3.48	.64	9.00	2.13	11.13	88.87	1.0315	10
„ XV.	4.82	3.54	.57	8.93	2.71	11.64	88.36	1.023	5

Numbers VII., XIV., XV., were known to be pure milk.

Analysis.	From Total Solids.		From Solids not Fat.		From Sugar.	
	Pure Milk.	Added Water.	Pure Milk.	Added Water.	Pure Milk.	Added Water.
No. I.	67.52	32.48	67.47	32.53	65.00	35.00
„ II.	72.16	27.84	72.15	27.85	78.41	21.59
„ III.	79.20	20.80	81.39	18.61	85.00	15.00
„ IV.	74.76	25.24	76.28	23.72	76.37	23.63
„ V.	91.00	9.00	86.83	13.17	90.00	10.00
„ VI.	74.16	25.84	76.45	23.55	69.09	30.91
„ VII.	95.08	— 4.92	101.13	—1.13	89.55	10.45
„ IX.	78.40	21.60	79.03	20.97	80.00	20.00
„ X.	84.64	15.36	77.53	22.47	80.23	19.77
„ XI.	74.00	26.00	76.88	23.12	80.00	20.00
„ XII.	77.36	22.64	81.72	18.28	80.23	19.77
„ XIII.	81.12	18.88	81.83	18.17	84.77	15.23
„ XIV.	89.04	— 10.96	96.77	3.23	110.90	—10.90
„ XV.	93.12	— 6.88	96.02	3.98	109.55	— 9.55

The figures with the — sign before them show that this ingredient, instead of being below the normal amount, was present in excess.

These cases, with the exception of Nos. V., VII., XIV., and XV., were all carried into court, and convictions were secured. No. V. it was thought not advisable to prosecute, though there could be but little doubt of the adulteration. The other three, as before stated, were pure milk, and each one of these three rises in one determination above the standard chosen; and, if they had been brought to me to be examined as adulterated milks, I should have refused, as I did in the case of No. V., to appear against the seller, as in each case there would be a strong doubt in his favor.

A paper by Dr. Mott, of New York, on the milk from the right and left breasts of women, suggested to me that I should try similar experiments with the different quarters of the udder of the cow. This I have been enabled to do through the kindness of Dr. Sturtevant.

I had previously found that I could, without any extra effort, make from four to six complete analyses a day, if I had a complete set of apparatus for each analysis. Commencing work at 10 A.M., when the milk arrived at my office, the four analyses have been completed, except the reading of the volume of cream, by 6 P.M. Analyses Nos. XVI., XVII., XVIII., and XIX., were of milk yielded by the Ayrshire cow "Model of Perfection." She was eleven years old, and calved Dec. 31, 1875. Evening's milk, Aug. 13, 1876.

The milk was drawn from each teat into a separate vessel, and was brought to me next morning.

XVI.	Right forward teat,	yield	907. grams.
XVII.	Left forward teat,	yield	577. „
XVIII.	Right rear teat,	yield	680. „
XIX.	Left rear teat,	yield	577. „
		Total yield	2741. „

	XVI.	XVII.	XVIII.	XIX.	Average.
Cream	25.	42.	29.	24.	28.1
Sp. Gr.	1.025	1.024	1.026	1.028	1.0257
Sugar	4.09	2.18	3.44	4.20	3.72
Caseine	4.48	6.58	5.00	5.59	5.11
Ash	.68	.61	.66	.67	.66
Solids not Fat	9.25	9.37	9.10	10.46	9.49
Fat	5 59	4.43	4.39	3.84	4.68
Total Solids	14.84	13.80	13.49	14.30	14.17
Water	85.16	86.20	86.51	85.70	85.83
	100.00	100.00	100.00	100.00	100.00

The sugar in No. XVII. was tested a second time with the same results.

Analyses Nos. XX., XXI., XXII., XXIII. The above results varied so much that it was desirable to repeat this experiment, which was accordingly done with another cow, with the following results: —

Ayrshire cow "Tabitha;" feed, 4 quarts cob meal per day, hay, and corn fodder; age, 2½ years; calved last spring. Evening's milk, Nov. 19, 1875. Analyzed Nov. 21, 1876.

XX.	Right forward teat,	yield	624. grams.
XXI.	Left forward teat,	yield	624. „
XXII.	Right rear teat,	yield	680. „
XXIII.	Left rear teat,	yield	737. „
		Total yield	2665. „

	XX.	XXI.	XXII.	XXIII.	Average.
Cream, vol. p. c.	14.	11.	13.	10.	11.9
Sp. Gr.	1.032	1.031	1.0306	1.0315	1.031
Sugar	4.90	5.00	4.72	4.88	4.87
Caseine	3.53	3.42	3.61	3.48	3.51
Ash	.59	.57	.61	.64	.60
Solids not Fat	9.02	8.99	8.94	9.00	8.98
Fat	3.32	3.00	2.73	2.13	2.77
Total Solids	12.34	11.99	11.67	11.13	11.75
Water	87.66	88.01	88.33	88.87	88.25
	100.00	100.00	100.00	100.00	100.00

The variation in this case consists mainly in the amount of fat. This variation, as will be seen, amounts to 1.21 per cent. The averages for both the above milks were found by ascertaining the total weight of each product given by the teat, adding the four weights together and dividing by the total weight of milk yielded.

It is evident from these experiments that each quarter of the udder yields a milk that may differ considerably from that given by any of the other quarters. This, however, has only a scientific interest, as in practice the four quarters are drawn simultaneously and the average result is used.

Some further experiments were tried in reference to the influence of breed and feed on the quality of the milk. These are far too few in number to base any opinion on; but, so far as I have been able to carry them, they show the need of extended experiments on this subject, — experiments which should be carried over the space of several years, with analysis at least once a week, careful records being kept of temperature of the air, state of the weather, and general condition of the cow; and a sufficient number of cows of each breed should be employed, that the individual equation of the cow should be eliminated so far as possible. To be comparable, these analyses should be either made by one person, or, if made by several, they should be made by the same method, and these persons should compare their working by making several simultaneous analyses of the same sample of milk.

Analysis No. XXIV., Ayrshire cow "Georgie;" calved July 7, 1876; food, pasture, fodder corn, and six quarts of shorts. Evening milk, Aug. 7, 1876.

Analysis No. XXV., Ayrshire cow "Georgiana;" calved July 19; food the same as last. Evening milk, Aug. 7, 1876.

Analysis No. XXVI., Ayrshire cow "Georgiana;" feed for a week previous, green fodder corn and grass. Evening milk, Aug. 19, 1876.

Analysis No. XXVII., cow "Georgiana;" feed for the previous week, green fodder corn, grass, and three quarts corn meal per day. Evening milk, Aug. 28, 1876.

Analysis No. XXVIII., cow "Georgiana;" feed for the previous week, grass, and five quarts of shorts, and one quart of corn meal per day. Evening milk, Sept. 3, 1876.

These two cows were full-blood Ayrshire, mother and daughter. "Georgie" was imported, and "Georgiana" was calved in this country.

Aug 7 Aug 7 Aug 19 Aug 28 Sept 3

	XXIV.	XXV.	XVI.	XVII.	XVIII.	Average.
Cream vol. p. c.	14.	17.	20.	5.	6.	12.4
Sp. Gr. . . .	1.029	1.031	1.030	1.030	1.031	1.0302
Sugar	5.00	5.19	5.20	3.94	4.32	4.73
Caseine . . .	3.60	4.13	3.34	4.82	4.27	4.03
Ash	.59	.67	.60	.65	.64	.63
Solids not Fat .	9.19	9.99	9.14	9.41	9.23	9.39
Fat.	3.09	4.20	4.34	2.48	3.37	3.48
Total Solids .	12.28	14.19	13.48	11.89	12.50	12.87
Water. . . .	87.72	85.81	86.52	88.11	87.50	87.13
	100.00	100.00	100.00	100.00	100.00	100.00

Analysis No. XXIX., Jersey cow "Henny;" calved July 17, 1876; food, pasture and green fodder corn, two quarts mixed corn and oat meal, and one quart shorts per day. Evening milk, Aug. 6, 1876.

Analysis No. XXX., Jersey cow "Danseuse;" calved May 11; same feed as No. XXIX. Evening milk, Aug. 6, 1876.

Analysis No. XXXI., Jersey cow "Henny;" feed for the previous week, corn fodder and pasture. Evening milk, Aug. 19.

Analysis No. XXXII., Jersey cow "Henny;" food, pasture and corn meal. Evening milk, Aug. 27, 1876.

Analysis XXXIII., cow "Henny;" food, pasture and six quarts of shorts per day. Evening milk, Sept. 3, 1876.

	XXIX.	XXX.	XXXI.	XXXII.	XXXIII.	Average.
Cream vol. p. c.	27.	21.	22.	18.	13.5	20.3
Sp. Gr. . . .	1.027	1.031	1.030	1.033	1.030	1.030
Sugar	4.20	4.57	5.67	4.19	4.81	4.69
Caseine . . .	4.42	3.78	2.64	5.17	3.83	3.97
Ash	.59	.59	.62	.72	.61	.62
Solids not Fat .	9.21	8.94	8.93	10.08	9.25	9.28
Fat	4.72	6.61	5.07	4.35	4.78	5.12
Total Solids . .	14.01	15.55	14.00	14.43	14.03	14.40
Water	85.99	84.45	86.00	85.57	85.97	85.60
	100.00	100.00	100.00	100.00	100.00	100.00

It appears from the average of these two series of analysis that in this experiment the two breeds of cows gave milk that averaged almost exactly the same composition, with the exception of the yield of fat; the Jersey giving on the average nearly one half more fat than the Ayrshire. The average result of the thirty-four analyses of pure milk, twenty-two of which were reported last December, and twelve now, is as follows: —

Sp. Gr.	1.030
Cream vol. p. c.	13.8
Sugar	4.82
Caseine	4.06
Ash	.65
Solids not Fat	9.53
Fat	4.62
Total Solids	14.15
Water	85.85
	100.00

With these analyses to judge from, it seems to me that an inspector of milk is fully justified in asking a conviction from the courts, if, when the theoretical milk containing 12.5 per cent of solids is taken as a standard, each of the three proportions starting from total solids, solids not fat, and sugar, show an addition of fifteen per cent or over of water.

No specimen of pure milk that I have ever examined, or that I can find any records of, fails to the extent of fifteen per cent of indicated adulteration in all three of these particulars. And I may add still further, although the specific gravity of a milk is not regarded as a reliable indication of its purity, that, in every case of adulterated milk I have met with, the inspector was justified in his seizure, if the sp. gr. fell below 1.026.

The mistake is sometimes made of considering the estimation of added water as an absolute determination, entitled to the same weight as the actual analysis. But it must be evident to any one, on a few moments' reflection, that these estimations cannot be so regarded, and that they are only approximations, whose chief value is to show the courts how much the milk falls below a milk of fair quality; and, when taken in connection with the fact that pure milk never falls so far below this standard, they enable the court to judge intelligently whether there are fair grounds for considering the sample to be adulterated.

Boston, Nov. 27, 1876.

APPENDIX.

It having been suggested that the first run of the milk of a cow was much poorer than the strippings, and therefore a milkman, who was desirous of proving that his milk was unwatered, might procure an analysis of such a specimen, the following experiment was tried: —

Analysis No. XXXIV., cow "Georgiana," right forward teat. Even-

	Analysis No. XXXIV.				Average.
	No. 1.		No. 2.	No. 3.	
Sp. Gr.	1.029		1.032	1.027	1.029
Cream	6%		9%	11%	8%
Sugar	4.49		4.80	4.50	4.61
Caseine	3.06	3.01	4.25	3.90	3.65
Ash	.54	.54	.58	.54	.55
Solids not Fat	8.09	8.04	9.63	8.94	8.81
Fat	1.78	1.84	3.03	4.03	2.61
Total Solids	9.87	9.88	12.66	12.97	11.42
Water	90.13	90.12	87.34	87.03	88.58
	100.00	100.00	100.00	100.00	100.00

ing, Dec. 3, 1876. The milk was divided into three portions, as follows: 319 grams were first drawn into one bottle, 274 grams were drawn into a second, and the remainder of the milk, 100 grams, was drawn into the third bottle. These three samples of milk were brought to Boston next morning and analyzed, with the following results. No. 1 proving so poor, a second analysis was made of it. This did not change the figures to any amount.

The first drawing in this case, while showing a deficiency of total solids, and solids not fat, nevertheless has rather more than the average amount of sugar, so the rule laid down would fail to condemn this as a watered milk. No one, however, would hesitate a moment in saying that it was a very poor article indeed. "Georgiana's" milk, as shown all through this paper, is not a very rich milk.

The near approach of Ayrshire milk to woman's milk is worthy of remark. The average of many analyses of woman's milk, as given by different authors, is as follows: —

	Colored Woman's Milk Average of 12 Analyses, by Mott.	White Woman's Milk Average of 89 Analyses, by Vernois and Becquerel.	White Woman's Milk Average of 14 Analyses, by Simon.	White Woman's Milk Average of 14 Analyses, by Tidy.
Sugar	5.71	4.364	4.82	4.265
Caseine	3.32	3.924	3.43	3.523
Ash	.60	0.138	0.23	0.285
Solids not Fat	9.63	8.426	9.11	8.073
Fat	4.03	2.666	2.53	4.021
Total Solids	13.66	11.092	11.64	12.194
Water	86.34	88.908	88.36	87.806
	100.00	100.00	100.00	100.00

These differ fully as much among themselves as any one differs from the average of Ayrshire milk, as given. Any tampering with Ayrshire milk, such as adding sugar and water to it, in order to make it more nearly resemble woman's milk, will therefore evidently do more harm than good: it is free from the excess of fat which oftentimes renders Alderney milk unfit for food for delicate children, and I have been assured by those who have used it that it makes an excellent substitute for woman's milk. For children's food, it evidently needs

nothing done to it, except warming it slightly, so as to take the chill off.

In this connection, I think I am justified in saying that no one cow's milk is as uniform in composition as the milk of a herd of cows, and that, if a uniform diet is wished for a child, it will be much better secured by mixing the milk of a number of cows, than when it is attempted by trying to secure the milk of a single cow. Since, as we see, the milk of any one of the cows taken varies very considerably.

Boston, Dec. 7, 1876.